Mathematical and computational methods in theoretical biology
16:215:600:02 (Fall, 3 credits)

Meeting times and place:
ENR room 145
Mondays and Wednesdays, 10:20am-11:40am

Professor: Dr. Juan A. Bonachela
Contact information: ENR 134, juan.bonachela@rutgers.edu
Office hours: Please send an email to schedule a meeting.

Course description: In this course, we explore theoretical models as a vehicle for understanding biological systems from a different perspective. We will review classic as well as state-of-the-art models, and the different mathematical and computational techniques required to analyze them. We will dissect and understand the models and assumptions involved, with the ultimate goal of learning how to construct and modify them, and tailor them to specific systems and biological questions.

Learning goals:
- Understand how models are developed and used in theoretical biology.
- Biological meaning and interpretation of the different terms and outputs of models.
- Understand the different analytical and computational techniques used to analyze and extract biological information from mathematical models.
- Develop critical thinking regarding assumptions and level of detail needed to model specific biological systems.

Grading: Attendance, participation, final project (presentation and report).

Recommended textbooks:
- Hastings, A: "Population biology: concepts and models"
- Otto, S and Day, T: "A biologist's guide to mathematical modeling"
- Murray, J: "Mathematical Biology: I. An Introduction"

Tentative topics:
- Does biology have laws?
- Exponential and logistic population dynamics.
- Population growth in controlled environments.
- The role and meaning of allometries in models.
- Trade-offs.
- Trait-based modeling.
- Predator-prey interactions.
- Evolutionary dynamics.
- Spatio-temporal patterns.
- Technical topics to learn how to analyze mathematical models and implement them in the computer (concept of derivative, integral, units, numerical integration, etc).

Final project: Free topic, but needs to incorporate ideas and techniques learned in the course. Results will be presented in class and in a written report.

Tentative schedule:

Date	Topic
09/07/2022	Introduction.
09/12/2022	Why bother. Figures. Meaning of equations, variables, parameters, units.
09/14/2022	Derivatives, discretization, and stationarity.
09/19/2022	Paper discussion: biological laws (Turchin; Bacaër — book chapter).
09/21/2022	Model terms and where they come from.
09/26/2022	Paper discussion: Chemostats (talk slides).
09/28/2022	Trait-based models. Model parametrization, allometries, and trade-offs.
10/03/2022	Paper discussion: allometries (Pawar et al; Brown et al).
10/05/2022	Solving mathematical models with the computer.
10/10/2022	Paper discussion: trade-offs (Litchman et al.; Edwards et al).
10/12/2022	Stability of models with one equation.
10/17/2022	Paper discussion: trait-based models (Litchman and Klausmeier; Follows et al).
10/19/2022	Stability of models with more than one equation.
10/24/2022	Paper discussion: plasticity/law of mass action (Grover; Bonachela et al).
10/26/2022	Discussion on system chosen for project; analytical/numerical tools available.
10/31/2022	Paper discussion: predator-prey models (Volterra; Holling).
11/02/2022	Project work session
11/07/2022	Paper discussion: evolution/adaptive dynamics (Brännström et al; Verdy et al).
11/09/2022	Project work session
11/14/2022	Paper discussion: Ecological transitions (Scheffer et al; Lenton)
11/16/2022	Project work session
11/21/2022	Paper discussion: Turing patterns (Murray; Klausmeier).
11/23/2022	Project work session
11/28/2022	Project work session
11/30/2022	Project work session
12/05/2022	Project work session.
12/07/2022	Project work session. Project report due.
12/12/2022	Presentation and discussion
12/14/2022	Presentation and discussion

Academic Integrity: Your learning experience depends on your academic integrity. You are expected to adhere to University policies and code of conduct (http://academicintegrity.rutgers.edu). These principles forbid plagiarism and require that every Rutgers University student i) properly acknowledge and cite all use of the ideas, results, or words of others; ii) properly acknowledge all contributors to a given piece of work; iii) make sure that all work submitted as his or her own in a course or other academic activity is produced without the aid of unsanctioned materials or unsanctioned collaboration; iv) treat all other students in an ethical manner, respecting their integrity and right to pursue their educational goals without interference. This requires that a student neither facilitate academic dishonesty by others nor obstruct their academic progress. Violations of academic integrity will be treated in accordance with university

policy, and sanctions for violations may range from no credit for the assignment, to a failing course grade to (for the most severe violations) dismissal from the university.

Diversity and Inclusivity Statement: In keeping with Rutgers's mission statement, this class strives to be an inclusive learning community, respecting those of differing backgrounds and beliefs. As a community, we aim to be respectful to everyone in this class, regardless of race, ethnicity, religion, gender, or sexual orientation.

If you go by a different name than what is on the class roster, please let us know. Using correct gender pronouns is important to us, so please do not hesitate to share your pronouns with us.

We are committed to supporting the learning of all students in our class, and recognize that you may experience a range of emotional, physical, and/or psychological issues, both in and out of the classroom, that may distract you from your learning. If you are experiencing such issues, please do not hesitate to let us know so we can make the necessary accommodations and/or come up with a plan to ameliorate the impact on your learning.

If you have or think you have a disability (learning, sensory, physical, chronic health, mental health or attentional), please contact the Office of Disability Services (ODS). If you have already registered with the ODS, please meet with us as soon as possible to discuss your accommodations in the course.

Special COVID19 considerations:

We understand that this is an unusual situation and that unanticipated personal issues may arise. It is important that you communicate with us if any special circumstances make it impossible or risky for you to attend class or complete assigned classwork. We will try to find a solution being both flexible and fair.

Other important information:

- Wear masks while in the classroom: Masks must be worn during class meetings; any student not wearing a mask will be asked to leave.

- In the classroom: Please make sure you wear your mask at all times. Please arrive only a few minutes before the lecture starts. Occupy seats as you enter, and keep at least one seat of separation with the next student. When the class is dismissed, please exit in order to minimize crossing paths with other students. Clear exits as soon as possible.

Additional resources: https://success.rutgers.edu/

Disclaimer: Please note that the syllabus and schedule are flexible, and therefore changes can occur if they improve the student experience and/or help the student achieve the learning goals above.